Plinius Conference Abstracts
Vol. 17, Plinius17-66, 2022
https://doi.org/10.5194/egusphere-plinius17-66
17th Plinius Conference on Mediterranean Risks

How is the reverse orographic effect on hourly extreme precipitation reproduced by a high resolution climate model?

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Increasing extreme precipitation intensity at short duration is reported in recent literature and related to the global warming. For improving risk management and adaptation to changing climate, it is important to estimate the changes in hourly extremes, because they cause numerous hydro-geological hazards. High resolution climate models (Convection-permitting models, CPMs) resolve the scales at which convective processes occur, and can provide higher confidence in the future estimates of hourly precipitation than coarser resolution models. However, since actual CPM runs are available for short time slices (10–20 years), estimation of extremes by using classical Extreme Value approaches is difficult. Novel methods based on the concept of ordinary event have shown the capacity of deriving reliable frequency analyses from short data records, and they can be successfully applied to CPMs.

Recent literature reported distinct orographic effects on precipitation extremes. In particular, decreasing intensity with elevation for hourly extremes is found ("reverse orographic effect") as contrasted with the orographic enhancement of precipitation for long durations. The reverse orographic effect was tentatively associated to orography-induced turbulence. These processes could be sub-grid even for CPMs, so it is crucial to understand whether and how CPMs can represent the orographic effect before using the simulations to project future extremes in mountainous areas.

We focus our study on an orographically complex area in the Eastern Italian Alps. Precipitation data comes from: i) ~170 5-min resolution rain gauges (our benchmark), ii) CPM simulations from COSMO model, run at 2.2 km spatial resolution and 1h time-resolution. The model is driven with ERA Interim re-analyses for the period 2000-2009. A storm-based statistical method is applied to both observed and simulated time series, and we use a Weibull distribution for modelling the upper tail of ordinary events. We derive the distribution parameters and extreme return levels up to 20-year return period for durations between 1 and 24 h. We look at their dependence on elevation, and we quantify the bias between observations and CPM, the dependence of the biases with elevation.

Spatial patterns in the CPM biases on the annual maxima and the modelled return levels emerge for short durations, while a general better agreement between model and observation is found at the daily duration. For the 1h return levels, the bias depends on elevation, with increasing

overestimation with elevation, which implies a weak representation of the reverse orographic effect.

This work shows that we can have reliable estimates of high return levels from short CPM runs by using proper statistical methods. The results can improve our understanding of the changes in the meteorological processes underlying the changes in the precipitation extremes, and could help us develop adjustment approaches accounting for the role of orography at multiple durations.